design + nature

solving design problems with inspiration found in nature

melanie de cola

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"We live in challenging times in which the scarcity of natural capital and the destructiveness of current industrial methods have become all too evident. Our society is in need of new ideas, and we need these ideas now!

Designers have a critical role to play in generating new ways to think, act and live, but the new design brief for saving the world will demand that they learn more about how that world actually works. Luckily, at least in the biological realm, there is a treasure trove of tested answers to some of our most pressing problems. For the designer willing to enter the fascinating world of bioinspired design, the rewards will be great."

Tom McKeag

general introduction

1 : general introduction

how to use this manual

This manual is meant to offer insight into and inspiration from the world of nature and bioinspired design. It is meant to be browsed, not read page by page. The first section is meant to introduce designers to some basic processes in nature. Hopefully these examples will both explain some of the details of these processes and offer ideas for design innovation on all levels.

The second section contains diagrams of step by step processes you can follow to initiate some sort of meaningful study of nature into your design practice. I've offered a few different methods to speak to the varied situations where design problem-solving arises.

Next is a section of examples of inspirational organisms that can help speak to specific design challenges. These examples show design innovation in nature and will hopefully spur new (and more sustainable) solutions to our design problems.

Finally, I've included places to go, books to read and organizations to look to for further learning. **But most importantly GET OUTSIDE and see what you find!**

1 : general introduction

why look to nature?

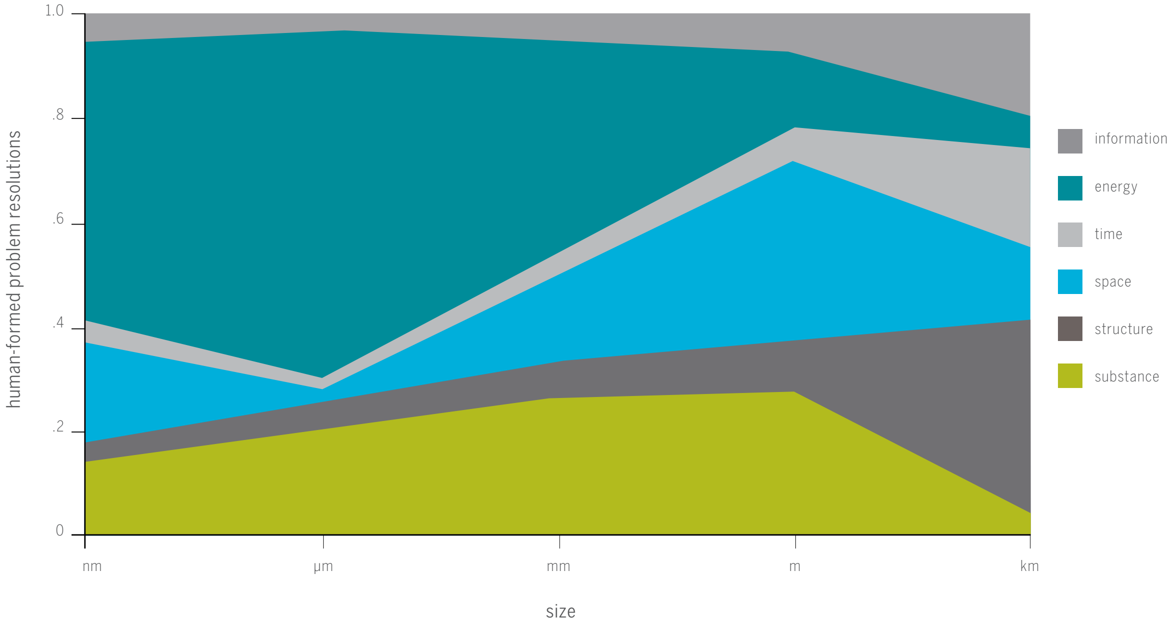
Scientists are no longer debating the fact that humans are having a negative impact on our global ecosystem. Many people have accepted this and are doing their part by recycling, turning their thermostats down and buying energy-efficient appliances and light bulbs. There's no denying that this is having an effect on a local and global scale. The problem is that it's not enough. We cannot compartmentalize our actions and expect to see wide-reaching results. There is a limit to what one person, one family or one city, or even one country can do.

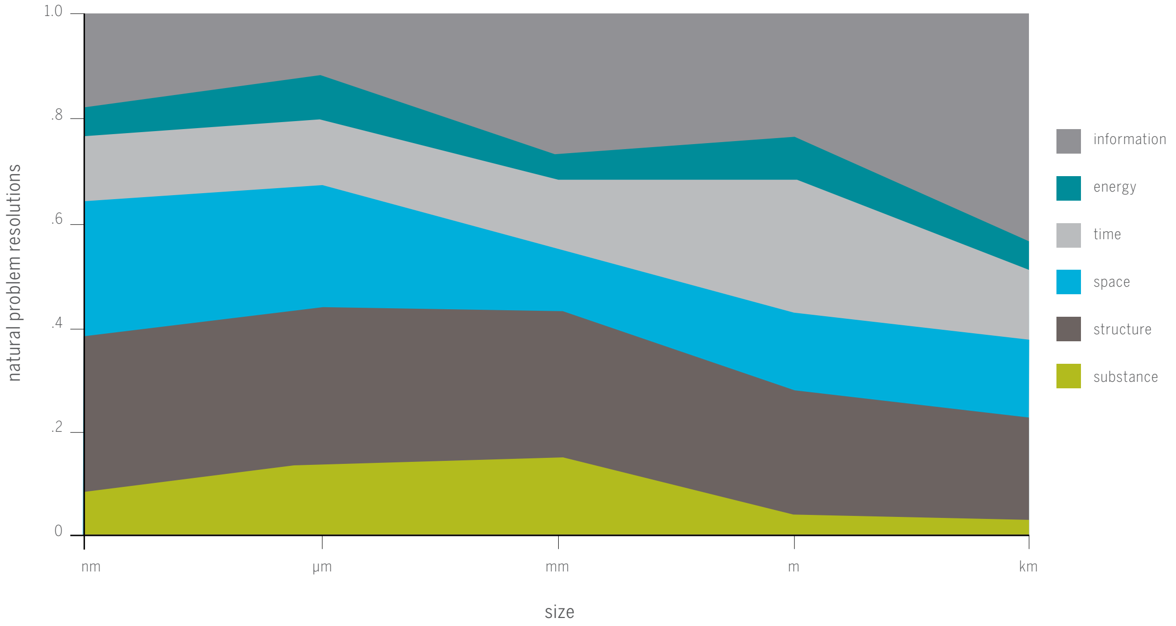
It falls to the designers and builders of the world in their many forms to take responsibility for their work and the consequences of their decisions. I'm talking about design in the broadest possible terms: how we think and the systems we create. By embracing new parameters for our solutions we can change the impact we are having on the planet and bring our species back into accordance with the laws of nature. We are not the first species to confront its own limitations, but we are certainly the most inventive. We can use innovation to change the future of the planet. We have already changed it for the worse, I believe it's now time to reverse our thinking, defer to nature and change our future for the better.

There are an estimated 1.4 million other species of living organisms on this planet and much we can learn from each one. We are part of a larger web of life that relies on even the smallest microorganisms. Just as the largest species in the ocean thrives on the smallest, we must consider the health and well-being of all species. There are even various species which can help to mitigate our own negative effects on the earth. Bacteria are ready-made waste disposal systems, while plants naturally filter toxins out of their environments. There is decreasing need for us to continue our heat, beat and treat method of production. It's time for us to step back and consider the larger picture or we will forever be remembered as the most destructive species this planet has ever seen.

introduction to natural processes

natural v. human design





Julian F Vincent, JR Soc. Interface, 2006 University of Bath

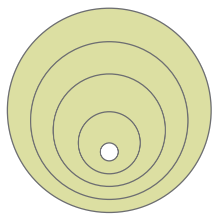
energy efficient problem-solving

I start this chapter off with these two graphs because I feel they visually capture the discrepancy between design in the worlds of man and nature. Julian Vincent (a professor of Biomimetics at the University of Bath) and his colleagues have studied problem-solving methods in both worlds and have arrived at these graphs illustrating the comparison. Humans (on top) rely on energy, mostly in heating, mechanical motion and pressure, to solve design problems and create products. They also rely heavily on substance instead of structure. Nature cannot afford to do this. Extreme heat and pressure are rare except where plates meet or volcanos appear.

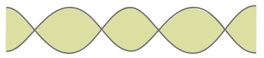
In comparison, nature forms its organisms and ecosystems with information, time and structure. Information is how organisms communicate; plants and insects send chemical signals to each other and DNA is formed from chemical compounds which rely on information and feedback. Time is needed for evolution, emergence and divergence. And structure is necessary to streamline and optimize forms in order to conserve energy. In a world where energy is scarce and waste must equal food, millions of years of evolution have already bested the solutions thought up by the minds of humans.

2 : introduction to natural processes

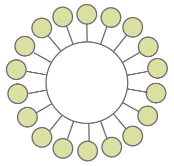
natural principles symbol set



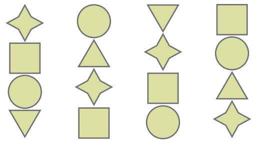
builds from the bottom up



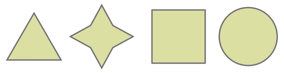
assembles itself into chains



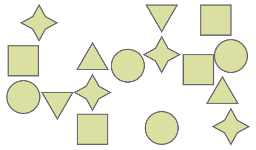
needs an inside and an outside



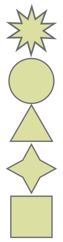
uses a few themes to generate many variations



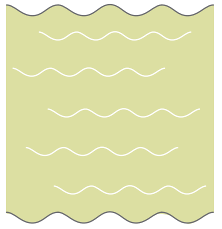
organizes with information



encourages variety by reshuffling information



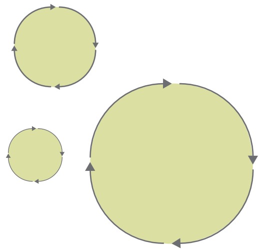
creates with mistakes



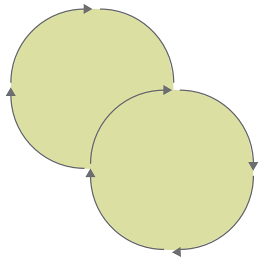
occurs in water

$C_6H_{12}O_6$

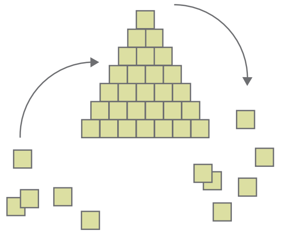
runs on sugar



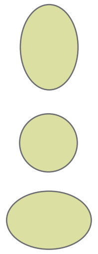
works in cycles



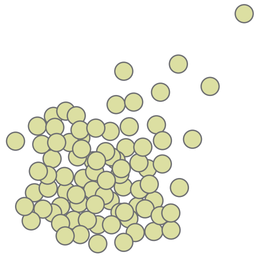
recycles everything it uses



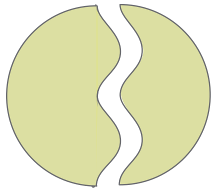
maintains itself by turnover



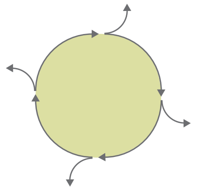
optimizes rather than maximizes



is opportunistic



competes within a cooperative framework

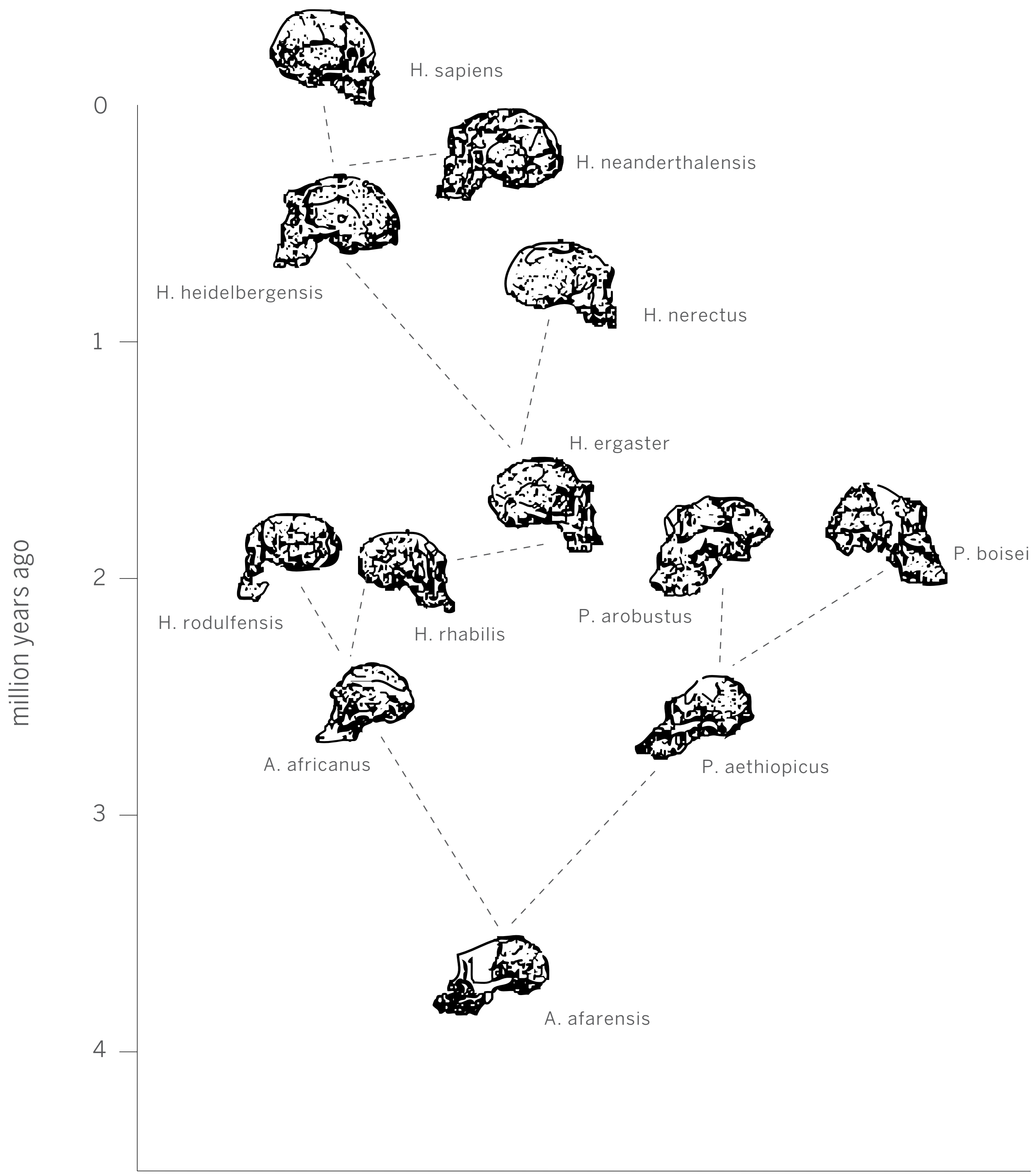


is interconnected and interdependent

These 16 symbols are my interpretation of Mahlon Hoagland's "Principles of Life" from his book The Way Life Works published in 1998. Hoagland was biochemist who helped discovered transfer RNA, the translator of the genetic code. His principles are a distillation of the forces at work in nature and are similar to the "Innovations in Nature" that Janine Benyus (author of Biomimicry: Innovation Inspired by Nature and co-founder of the Biomimicry Institute and Guild) speaks about. Nature designs within a framework and responds to a set of parameters. These symbols are meant to visually represent the principles that nature (life) adheres to: cooperation, interdependency, recycling, turning waste into food, optimization, variety, building in chains of information, utilizing structure, liking membranes, being opportunistic, utilizing mistakes, and building from the bottom up (small to large, organism to ecosystem).

What would happen if designers used these principles as constraints on their work? If you can employ just 1 or 2 of these principles, design can become a radically different discipline. If we can form our designs within the context of collaboration and cycles of reuse we can take a big step forward towards a more sustainable future.

evolution



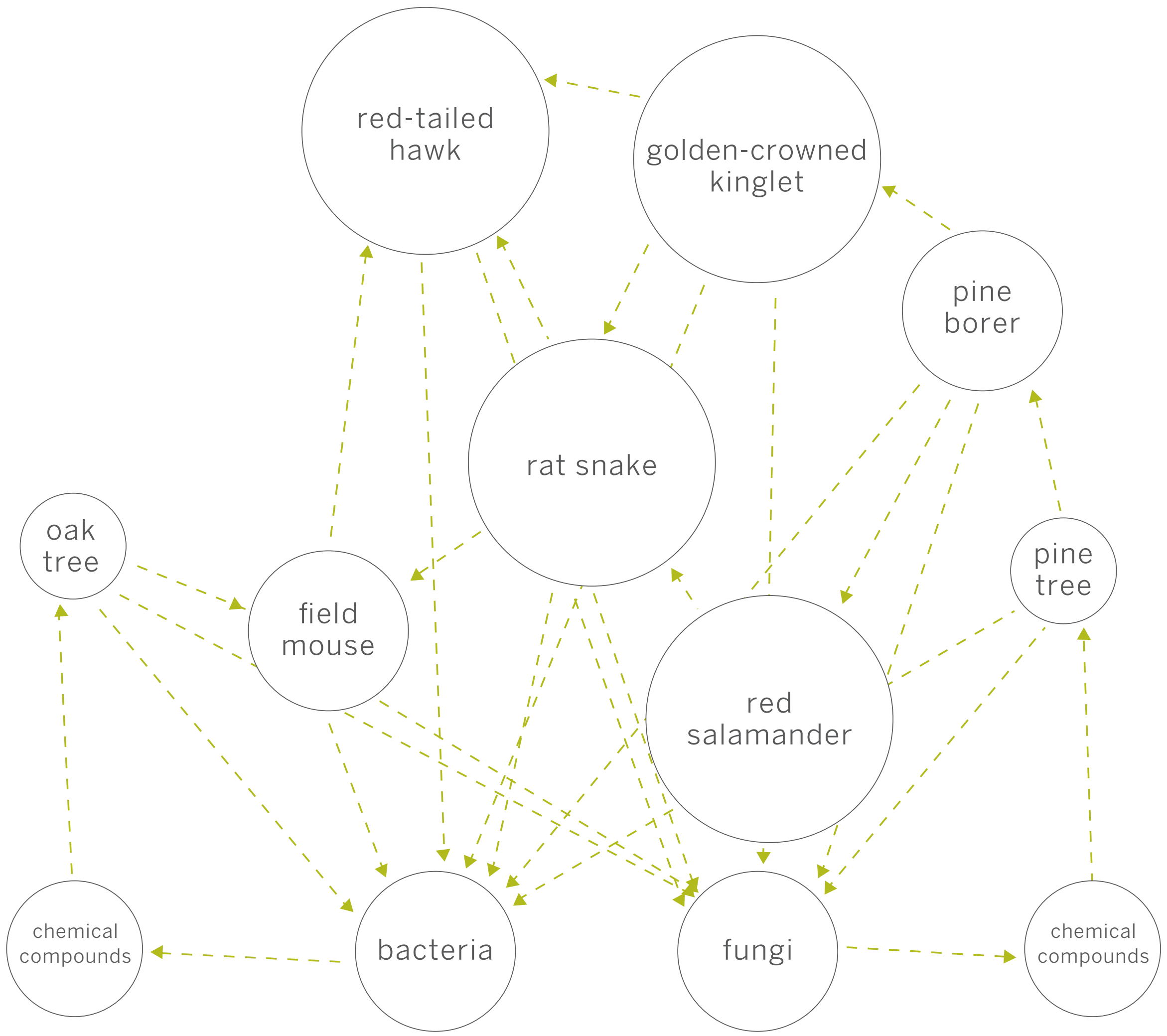
original chart from rationalrevolution.net

design innovation tested by time

Evolution is nature's intricate design process. It includes experimentation, biological testing, divergence, emergence, mutation and extinction. Wikipedia.org summarizes evolution this way:

> "...Evolution is change in the genetic material of a population of organisms through successive generations. Although the changes produced in a single generation are normally small, the accumulation of these differences over time can cause substantial changes in a population, a process that can result in the emergence of new species. Similarities among species suggest that all known species descended from a common ancestor (or ancestral gene pool) through this process of gradual divergence."

It is a process of continuous testing with sometimes deadly results. Our planet now benefits from millions of years of this testing, the result being a high level of biodiversity. With every year that humans inhabit the earth this diversity is being reduced and many species are disappearing, but it doesn't need to be this way, by looking to nature we can find better tools and inspiring organisms to emulate. A high level of biodiversity means that an ecosystem is healthy and offers many organisms and systems to study and learn from. It also requires a high level of cooperation with many species learning to exist together in one space.



webs + loops

Ecosystems are how species and habitats are interconnected and interrelated. They organize the complexity of diversity found in nature and create open and closed loops of interactions and relationships. Organisms rely on each other for food, shelter, protection, reproduction and many other things. All parts of the web are important, with the most important species being the keystone species which, in a sense, hold the entire system together by touching each part.

When we think of ecology we first think of the natural world but there is also such a thing as an industrial ecology, and there are many ways in which humans and societies can rely on each other. The best known example is Kalundborg, Denmark. Kalundborg has created a web of interrelated companies and services that all service and collaborate with each other. The parties involved are : Asnæs Power Station (which is coal-powered), Statoil Refinery, Gyproc (a sheetrock manufacturer), NovoNordisk (a biochemical and pharmaceutical company), and the city of Kalundborg which provides infrastructure. These companies exchange waste and services in a closed-loop system that virtually eliminates waste. If we can create more interdependent webs we can learn to view waste as opportunity, as nature does.

mathematics in nature

the Fibonacci sequence

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987 1597, 2584, 4181, 6765...

These numbers are more than just random listing, each number is made up of its predecessor + itself. If you place rectangles of these related dimensions next to each other and draw an arc through their opposite corners you will draw a Fibonacci spiral. This spiral and combinations of these numbers are often found in nature. Shapes made from these numbers are called golden and since the Renaissance, possibly even back to ancient Grecian times, are considered most pleasing to the eye.

Many flowers have petals, and plants leaves, that relate to this sequence whether in quantity or arrangement. Pinecones, fern leaves, pineapple and artichoke florets are arranged according to this sequence. The spiral aloe pictured at left has leaves that grow outward in two overlapping spirals which both contain Fibonacci numbers. Nautilus shells display the Fibonacci spiral in the growth and ratio of their shell sections and even the segments of our fingers relate in size according to Fibonacci ratios.

design methodology

3 : design methodology

the 4 bios

bioutilization
biomorphism
biomimicry
bioinspiration

bioutilization
biomorphism
biomimicry
bioinspiration

biological principles in design

These categories come originally from Tom McKeag, I have paraphrased and simplified the definitions.

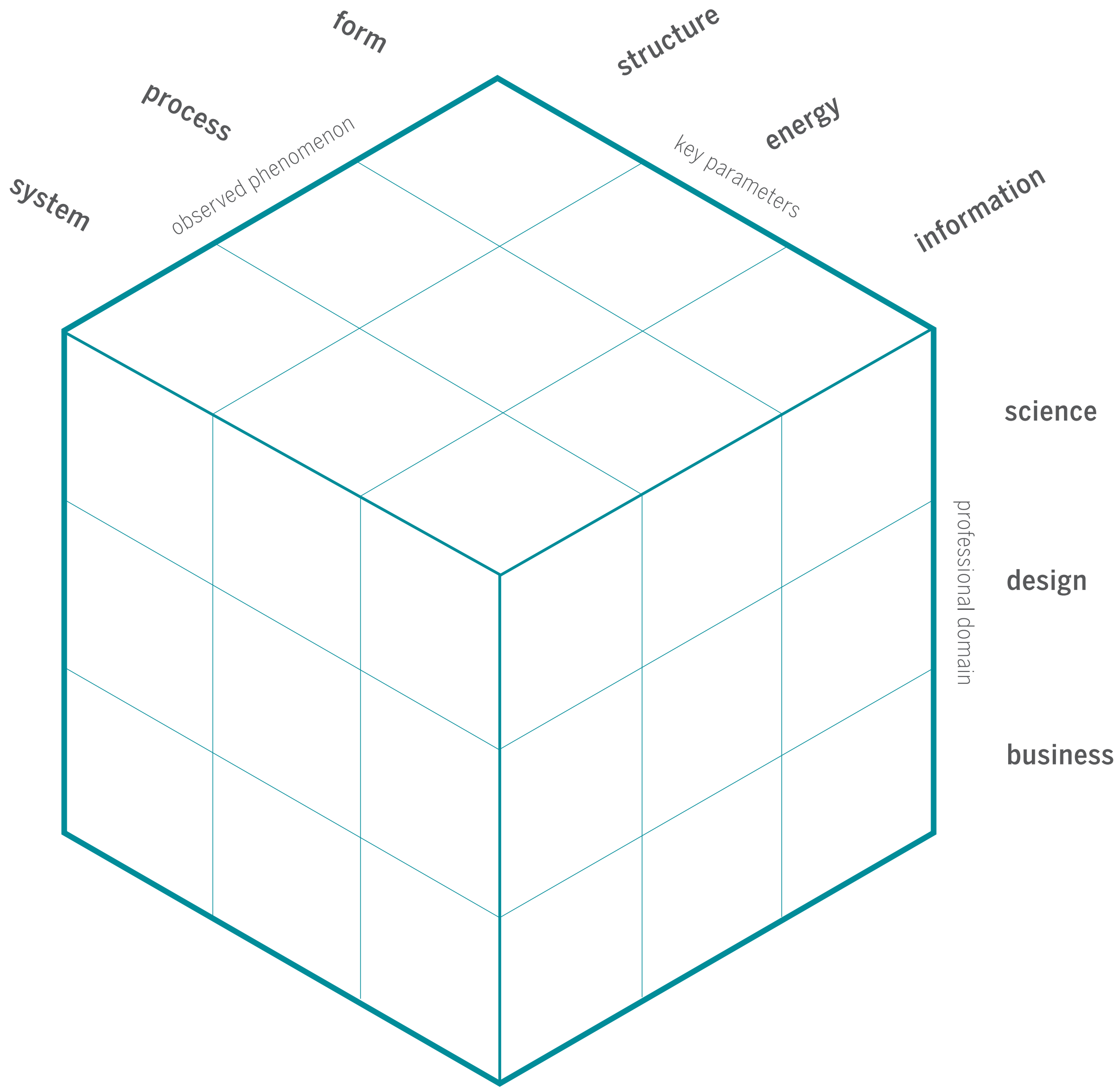
bioutilization : Using nature to solve design problems or to enhance existing human systems. Eg. John Todd's use of wetland plants to design a wastewater treatment infrastructure at the Omega Center for Sustainable Living.

biomorphism : Designing objects to look like natural forms, regardless of material or function. Eg. Chandeliers that look like deer antlers. It was also an art movement in the 1950s.

biomimicry : Studying natures forms, processes and systems to inform human design in the service of creating more sustainable solutions, especially if they function in closed-loop cycles. Eg. Using the spiral shape found at the center of a calla lily to create an impeller which circulates water more efficiently, see the work of Pax Scientific.

bioinspiration : Using nature's principles to create new design solutions that go beyond nature's processes. Eg. work being done at CiBER by Robert Full's students, who have created robots that mimic animal movement.

biodesign cube



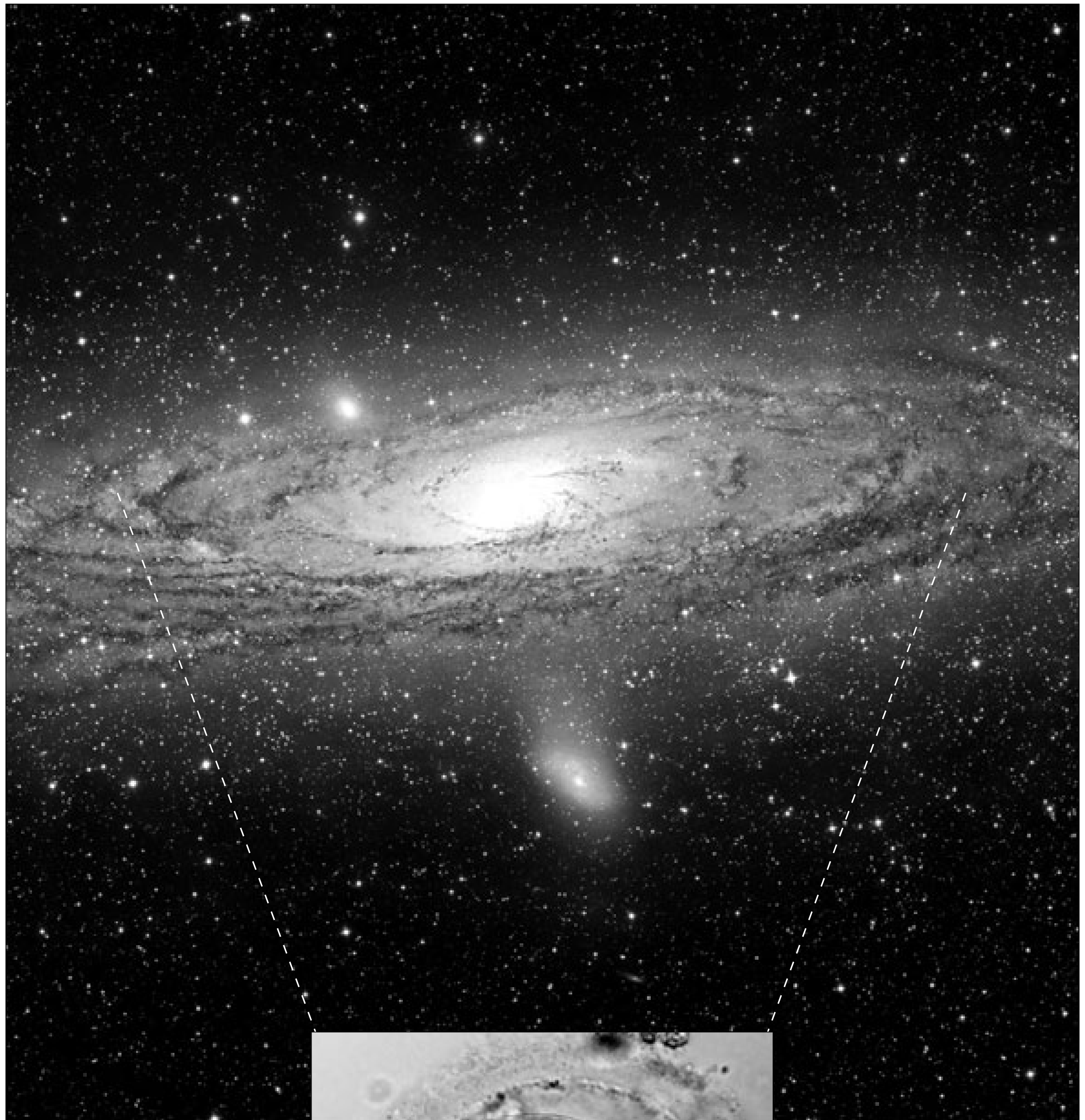
defining the parameter of the problem

This cube was created to distill some key parameters to help site the design problem-solving process, specifically as it relates to bioinspired design. This cube is broken down into three realms, each containing three sub-categories. As part of the distillation process, siting your problem within one of these quadrants will help you decide where to start your research and what kind of organisms to investigate and what kind of experts to consult.

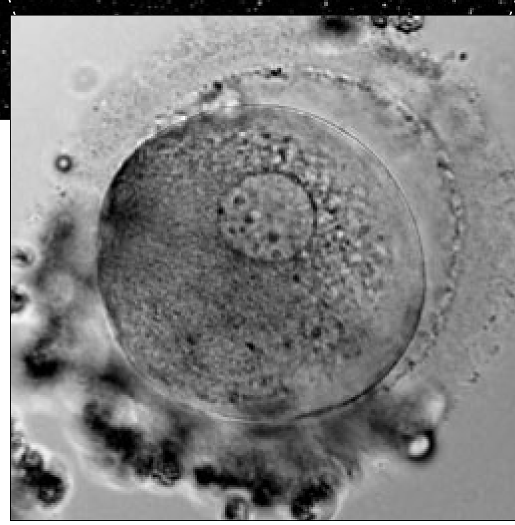
Do you need to find a solution that is streamlined in turbulent conditions? You'll find yourself in the structure, form and probably science quadrants. This is a good place to be when starting your research, you can start reading science periodicals, learning about air and water resistance and visiting industrial design websites. You may want to start consulting with physicists as well.

Does your design need to be light and use very little energy? You're probably in the energy, design (or business) and systems quadrants. Start by consulting with an mechanical engineer and researching lightweight organisms such as jellyfish. Learning how plants such as dandelions distribute their seeds could also lead to lightweight solutions.

the powers of ten



Andromeda Galaxy © Jerry Lodriguss



© Stemagen

scaling up + scaling down

Most designers are familiar with the 1977 film "Powers of Ten" by Charles and Ray Eames. This problem-solving method takes inspiration from that exploration. In the film the viewer travels from the human-scale outward to that of galaxies and back down to the sub-atomic. These scale changes can be helpful to remember in the design process. Siting and right-sizing your design solution are important parts of problem-solving. Expanding outwards and exploring the larger context that your solution or product lives in can help with optimization.

Explore similar existing designs solutions, research the materials you're considering using, the audience you are appealing to, the supply-chain your design will rely on and the life-cycle your design might have. Don't forget the minute pieces of your solution as well as the grand scheme. When your product breaks down, what chemicals will it release? Can it be upcycled into a new product? Can you use a composite instead of gluing parts together which often requires toxic solvents to reverse. Remember that everything you create exists in a larger context, both environmental and cultural, whether you're working with nanotechnology or urban planning.

3 : design methodology

the 5 whys

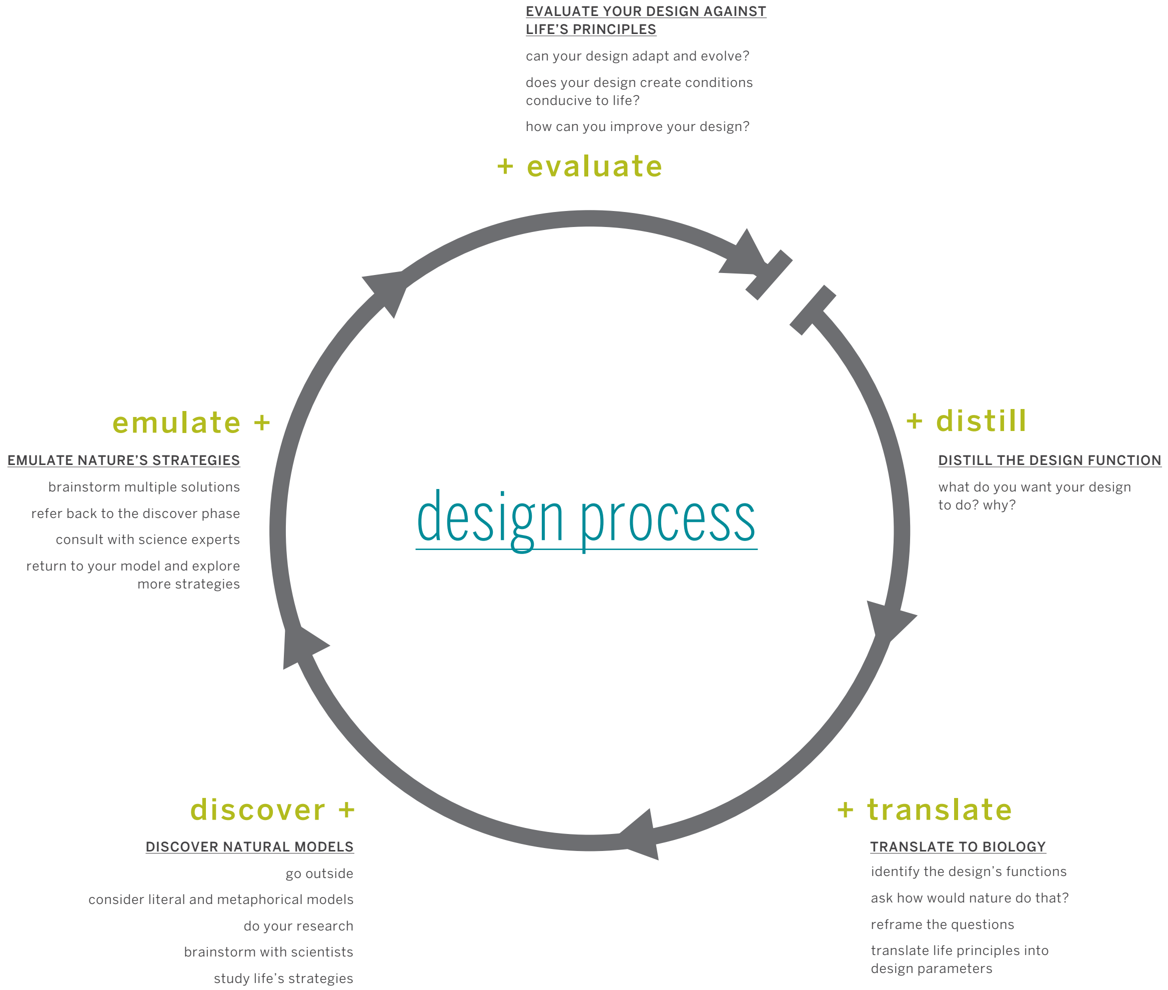
getting to the essence of your design problem

The 5 whys is pretty much just what it sounds like, it's a process that can help you distill the very essence of your problem. Here's an example :

Design problem : rainwater run-off in urban settings are carrying pollutants into natural areas and poisoning fish.

Why is this a problem? Because fish species are dying.
Why are they dying? Because chemicals are getting into their water source.
Why are chemicals in their water source? Because they are running-off from areas upstream.
Why are they running-off? Because there are no laws in place to keep chemicals away from drainage areas.
Why are there no laws? Because local government is not aware there is a problem.

Solution : Would it make more sense to try and stop the chemicals from entering the water cycle by creating filtration systems at drainage points or would creating an awareness campaign to get local citizens and businesses to keep them from dumping chemicals in the first place be more effective? Same problem, different solutions.



original design spiral concept by the Biomimicry Guild and Carl Hastrich

the bioinspired design cycle

The chart at left is an attempt to create a process for designers to follow when seeking to create bioinspired design solutions. It is my modified version of an original design spiral created by the Biomimicry Guild.

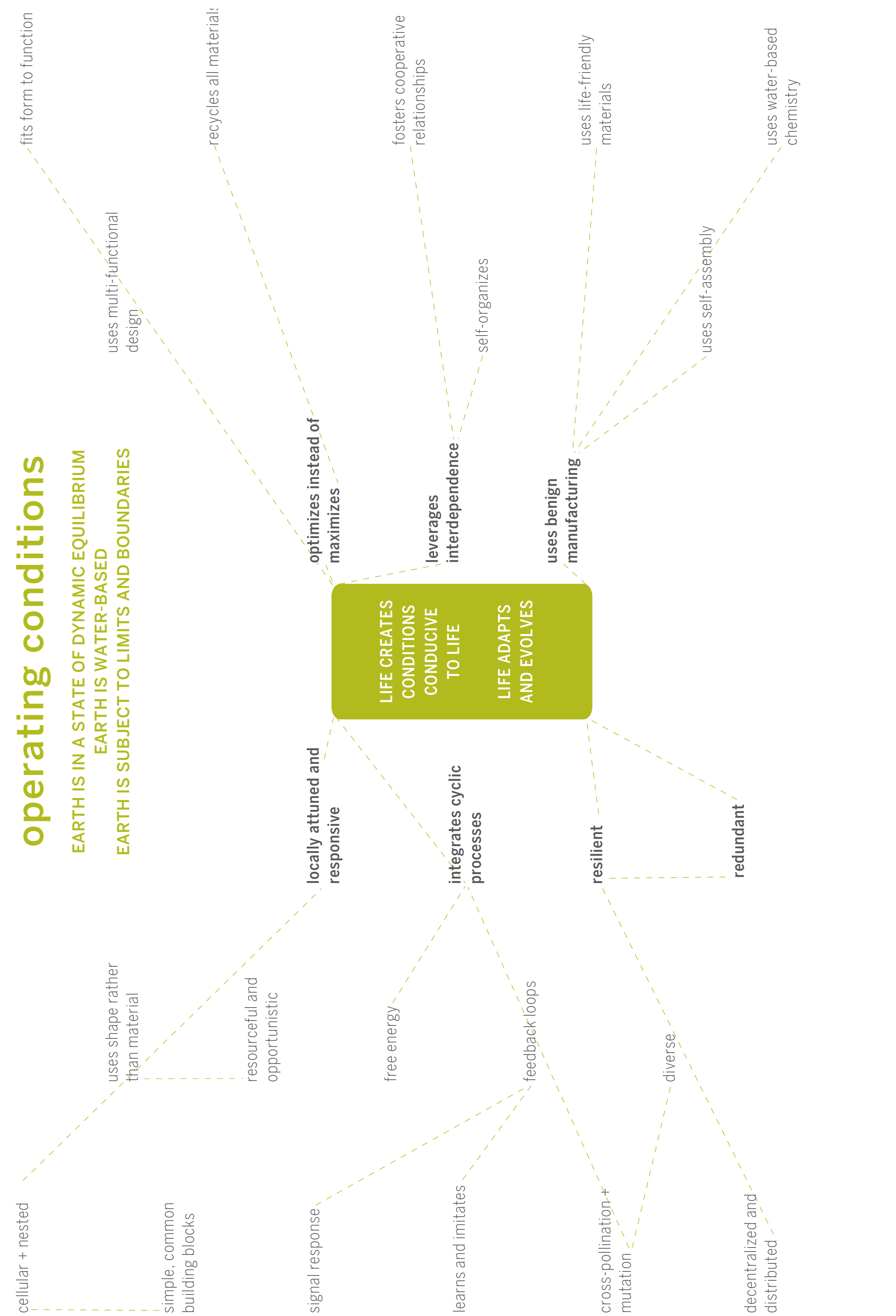
distill : Focus on the main design problem you're trying to solve, if you can decide on one element to fix or one question to ask you'll have an easier time finding a solution.

translate : Find a similar situation in the natural world. Ask yourself "How would nature do that?"

discover : Get outside the confines of your studio and your normal routine. Take enough time to allow previously unthought-of solutions to arise.

emulate : As you begin to get ideas, brainstorm and consult with experts in the field, find people who have studying your inspirational organism for years.

evaluate : Take time to test your solution and see if it solves your design problem in an elegant and efficient manner. If it does not refine it or start again.



original butterfly chart by the Biomimicry Guild

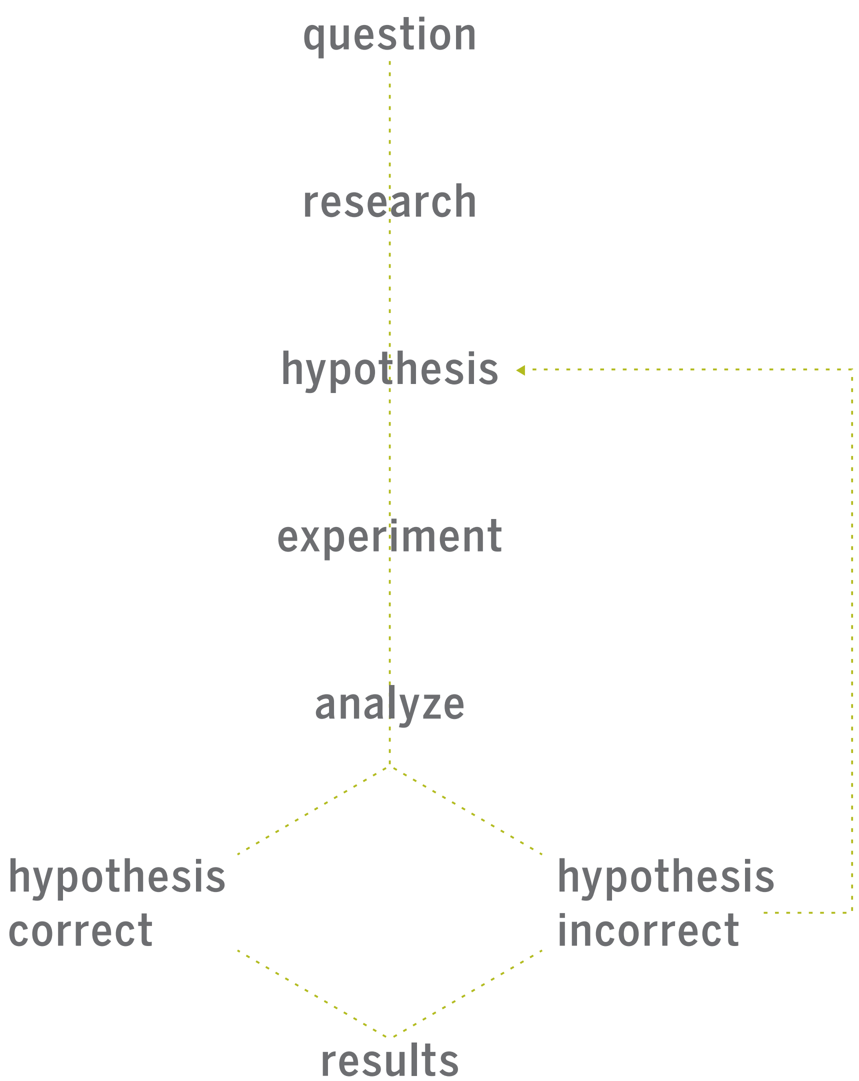
nature's principles web

If you feel you don't need a step by step process to follow, explore some of the basic concepts and strategies that nature employs. These ideas are similar to the 16 Natural Principles introduced in the last chapter but are connected through a simple hierarchy. Try choosing one that at first seems like it has nothing to do with your design problem, or an incongruous match-up. Let experimentation and unexpected results help drive your process. Is there a way you can build-in a collaboration with someone outside of your field? Finding new people to bounce ideas off of can often start new conversations and lead to new solutions. this is where naturalists and scientists can be most helpful.

Could you solve your design problem using recycled pre-existing materials? Can you nest your solution within and existing framework or system? Can you push the energy efficiency of your design? Can you minimize material use by designing a more streamlined shape? Would creating a repeating cycle help strengthen your design? How would nature solve the problem?

Pick and choose some principles that could help with your ideation and process. If you hit roadblocks, start over with new principles, try a choosing at random and seeing what evolves in your thinking.

the scientific method

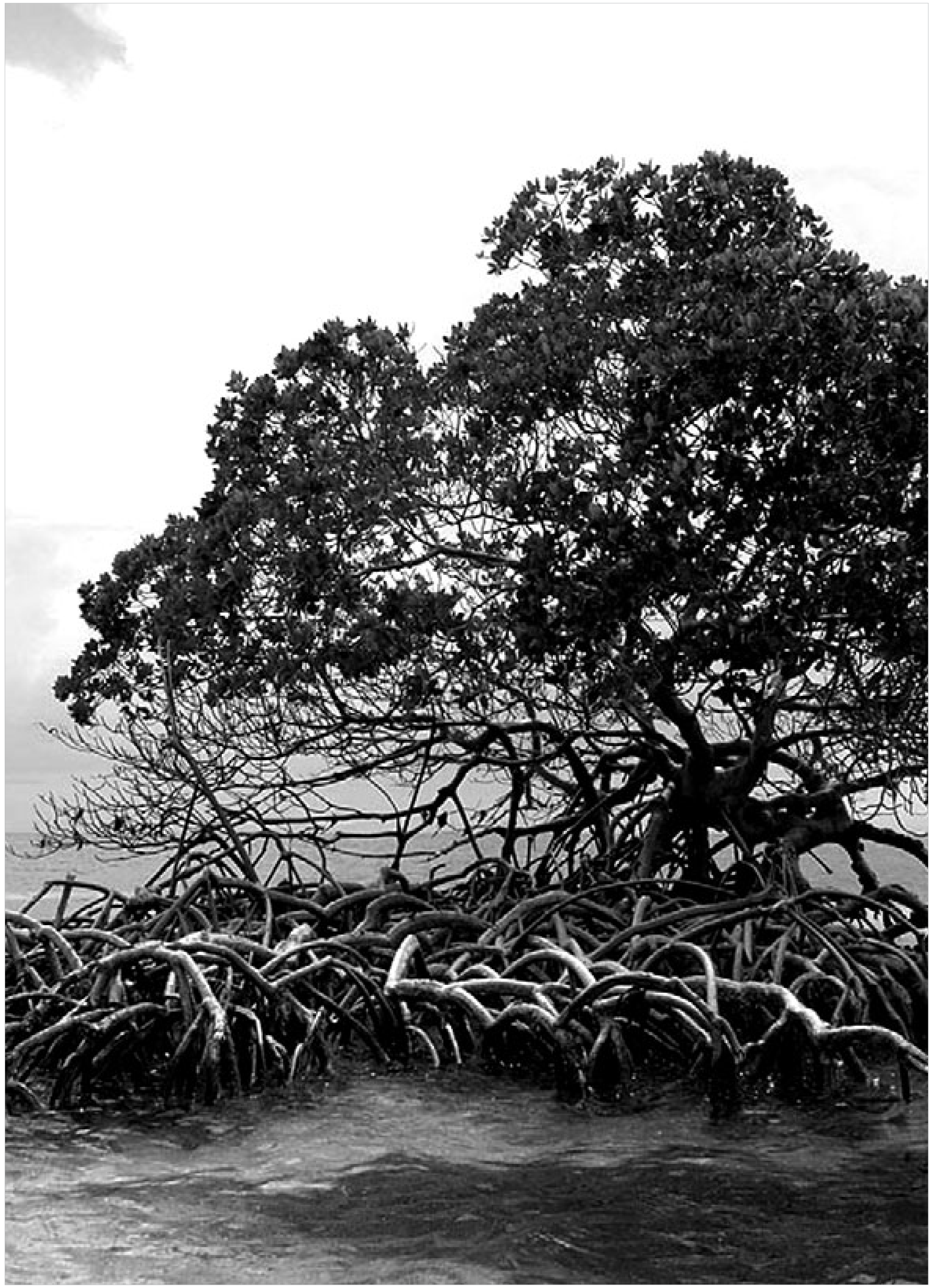


returning to high school science

Not surprisingly one of the first things we learn in science class can help with the design process. If you are looking for some super-straightforward steps to follow or are still in the experimentation phase, the scientific method can be a good place to start as it is time-tested.

First decide on the essence of the problem you're trying to solve, get outside or do some research on possible inspiration from nature. Seek out more information about the organism/s you've chosen. Does the organism solve your problem in an elegant and efficient way? Was your initial hypothesis correct about your solution or do you need to find a new source of inspiration? Can you design a solution that is better than an existing solution in nature? Let a process of hypothesis, experimentation and testing guide you until you arrive at your design solution.

natural design innovation



original photograph by J03P

dealing with salt + fresh water

red mangrove

rhizophora mangle

Mangroves are halophytic (salt-tolerant) trees which live at the edges of oceans and bays where the salt content of the water can be as much as 3.5%. Most plants cannot live in such conditions because salt throws the cells of living organisms into disequilibrium. Salt draws water out of living cells and can cause them to rupture. But mangroves have adapted special solutions to the salty conditions. Their cells have a high level of salt in them already which keeps water from wanting to escape. They also extract salt in the water washing over their roots and by using the energy of transpiration. In the narrow capillaries of their roots they suck the sea water upwards and filter it through thin membranes. Salt crystals are left behind on leaves and the water that remains is now fresh and nourishing.

Possible applications

desalination factories,

personal desalination and drinking devices,

coastal water intake systems,

water storage and filtration systems in the desert.

original photograph by Gwylan

surviving both dry + wet conditions

virginia glasswort

salicornia virginica

Glasswort (or pickleweed) is a succulent plant which lives primarily in salt marshes. It, like the mangrove, is a halophyte. But it not only tolerates salt water but can also be left exposed by the tide for hours at a time. Like the mangrove, it also uses transpiration to expel salt from its cells, it moves salt upwards and allows the tops of its leaves to concentrate it, eventually causing them to fall off and expel the salt. In addition, glasswort has a few adaptations that allow it to be left exposed for extended periods without resulting in dessication (the state of extreme dryness). It has a waxy surface coating which keeps water in, its leaves are formed in segments to conserve water closest to the roots and it even has tiny hairs all over its surface to inhibit evaporation. All of these innovations result in a hardy salt marsh plant.

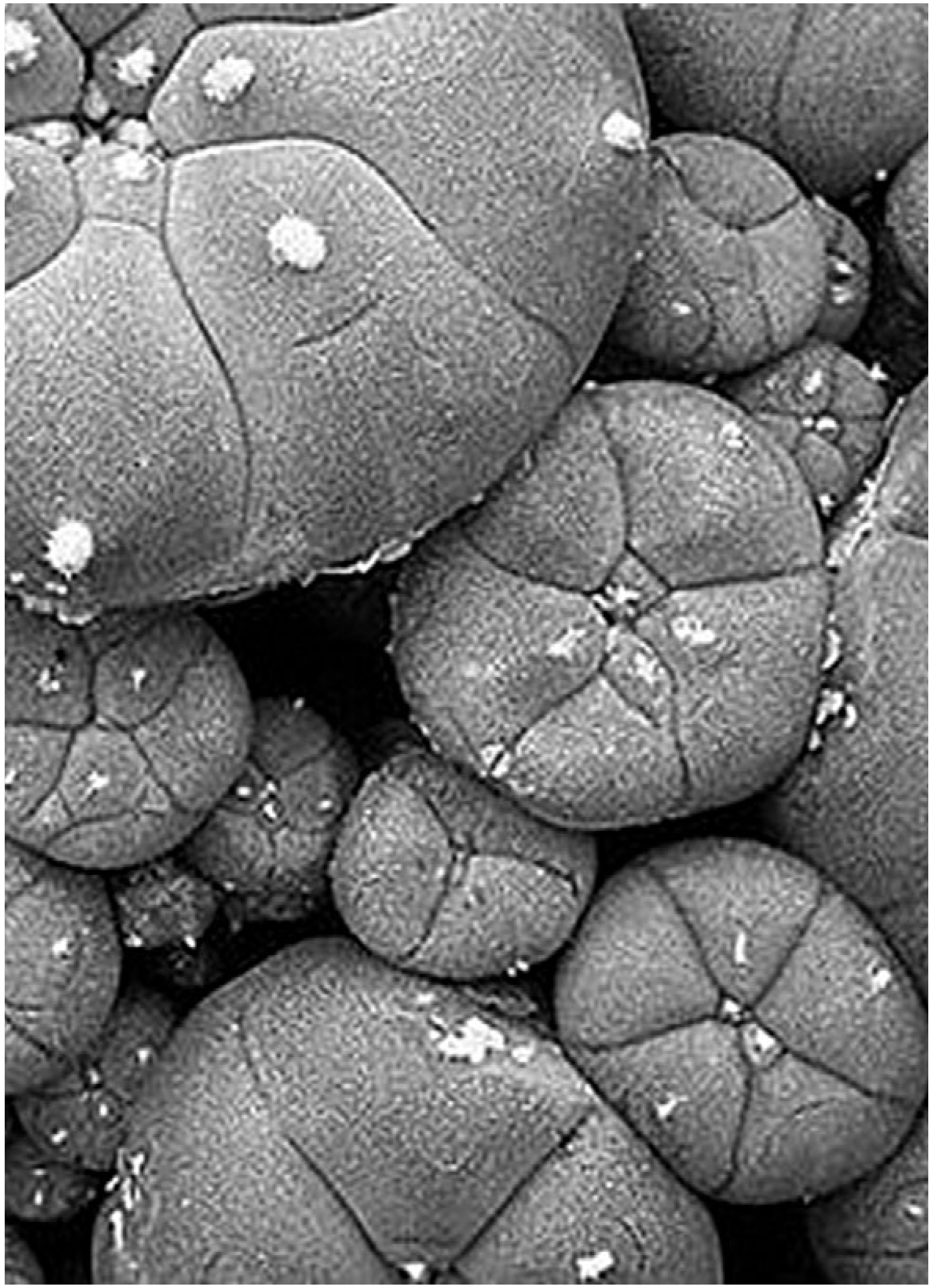
Possible applications

water storage tanks in dry areas,

water storage systems that can be moved from land to sea,

water filtration systems that passively desalinize water,

flexible water storage and filtration systems.



original photograph by Frank Vincentz

storing + collecting water

mescal cactus
lophophora williamsii

The mescal cactus has taken water storage and conservation to new levels, namely underground. Like all cacti and succulents, it is extremely water-tight and has a waxy skin to help seal water inside its leaves. The mescal, however, has adapted even further and has the ability to shrink and disappear below the surface of the ground around it. When the rains begin to fall again, the underground shoots break back through the surface of the earth and expand to store excess rainwater inside to save it for use in future dry times.

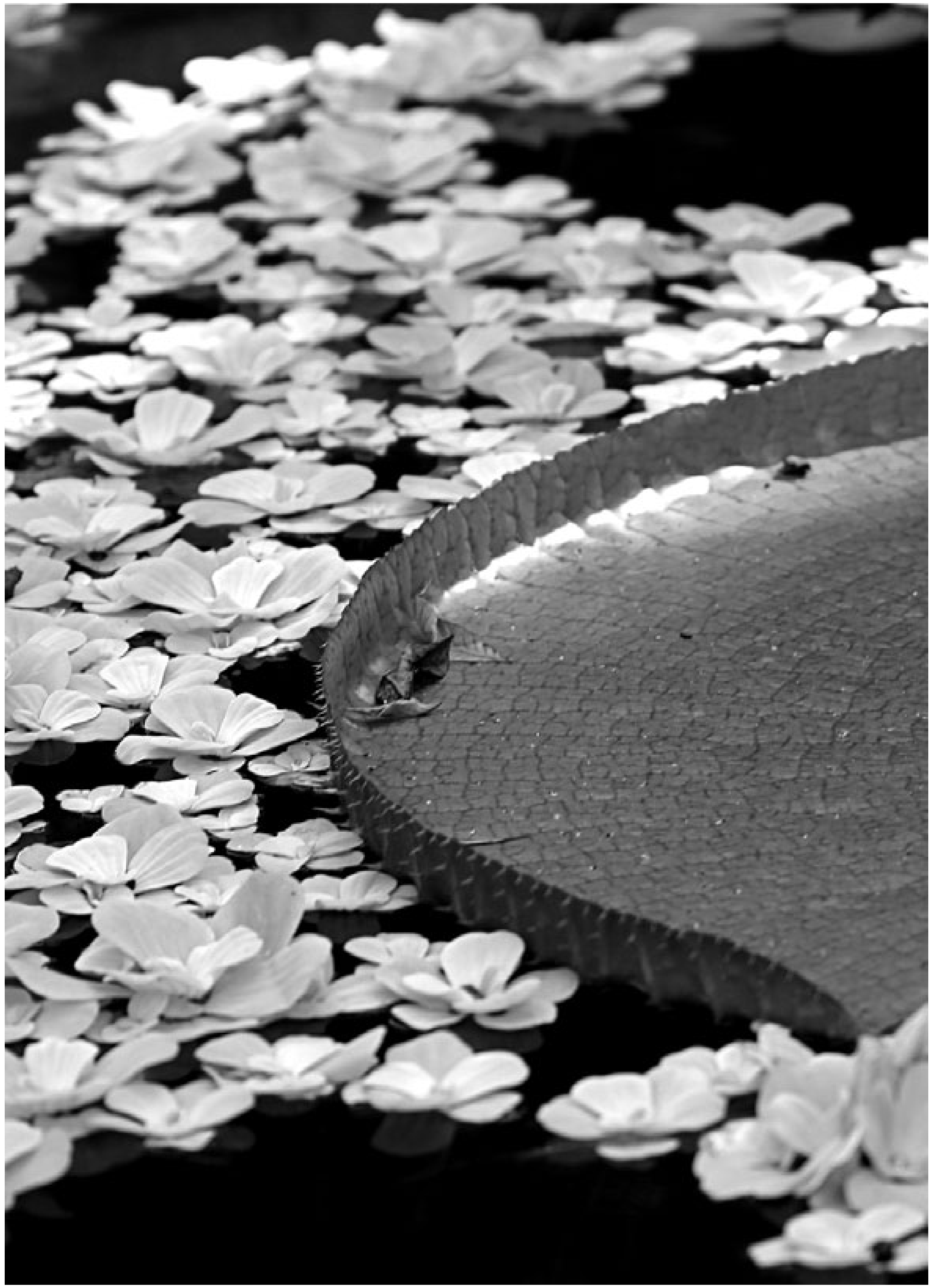
Possible applications

self-expanding water storage tanks and irrigation systems,

flexible piping and storage tanks,

pressure-responsive reservoirs and sewage systems,

materials that can intelligently respond and react to external moisture levels.



original photograph by Becca James

harvesting sunlight

giant water lily

victoria amazonica

The giant water lily is a master of photosynthesis, like all lilies it floats its leaves on the surface of the water in order to maximize sun exposure. Like its name suggests, the giant water lily can have leaves up to 10 feet wide which prohibits other plants from competing for sunlight. But it has even further adaptations, Its buds emerge covered in spines and as the leaves begin to open, the edges push competing leaves aside. A rim then forms around the leaf which can be up to six inches high. The giant water lily can easily monopolize the surface of a pond and become the primary photosynthesizer.

Possible applications

floating photovoltaics,

super-efficient photovoltaic arrays,

large, structural floating platforms,

floating energy collection and disbursement systems.

original photograph by Manuel Ramos

lack of sunlight

window plant
fenestraria rhopalophylla

The window plant is a desert dweller which lives in Southern Africa. It takes hold in the sand with a short but muscular root, it then puts down one initial bud below the ground. From this bud, succulent leaves sprout which are great at holding moisture. Being below ground is good for keeping the plant cool but it limits photosynthesis since only the tops of the leaves are exposed to sunlight. To compensate for this, the tops of the window plant's leaves are both flat and translucent. The pillar-like leaves enhance photosynthesis by filtering sunlight down a series of aligned translucent crystals of oxalic acid (which occur as a by-product the oxidation of carbohydrates). The light that filters through the leaves then encounters well distributed grains of chlorophyll and provides the plant with energy.

Possible applications

super-efficient photovoltaic cells,

daylighting techniques for buildings,

windows that let light in but keep heat out.

original photograph by dark orange

extreme heat

compass termite

amitermes meridionalis

Many organisms have evolved interesting ways to deal with overheated environments but the compass termite has even built a cooling system right into its housing. Its mounds are built in wedges are oriented North-South in order to both soak up and avoid sunlight at different times of the day. The East and West-facing sides of the mound maximize sun exposure in the cool mornings and evenings when the insects need extra warmth. But when the sun is at its hottest, directly up in the sky, the mound only show a sliver of a profile, keeping it cool. Indigenous people and contemporary architects have both replicated this structural technique in buildings that are sited in climates at both ends of the temperature spectrum.

Possible applications

architectural structures,

architectural siting,

passive heating and cooling systems,

hvac systems,

urban planning.

original photograph by Henk Wallays

extreme cold

Siberian salamander

salamandrella keyserlingii

The Siberian salamander has chosen a habitat that most amphibians would have a hard time enduring. Amphibians are ectothermic (cold-blooded) and generally cannot tolerate cold climates. But this salamander can survive in temperatures as low as -31˚F. It has adapted to the cold and produces special chemicals similar to antifreeze which replace water in its blood and cells to protect tissues from damage from sharp ice crystals. The animal can then remain functional even in freezing conditions. While some animals use glucose or glycerol to protect them from freezing, the specific chemical combination that the Siberian salamander uses is not yet known.

Possible applications

liquid storage with low freezing temperatures,

storage for medicines without freezing,

special food or drink for cold-weather explorers to prevent frostbite.

original photograph by Volker Wurst

symbiosis

poison dart frog
dendrobates pumilio

+

bromeliad
bromeliaceae

Many species have learned to co-evolve in order to increase their chances of survival. It can be advantageous to create partnerships that are mutually supportive. Poison dart frogs carry their tadpoles up into the rainforest canopy to live in the pools of water that collect as a result of the overlapping structure of bromeliad leaves. The tadpoles gain protection by being shielded from predators and the bromeliads benefit from extra protein from the dart frog eggs as the dart frog mother often revisits her tadpole, dropping an unfertilized egg into the pool for it to eat.

Bromeliads also have similar relationships with various types of tropical spiders who live in the leaves and often drop bits of their kill into the cups of the bromeliad. Some spiders have even learned to fish, catching insects that fall into the pools at the base of the bromeliads. Many spiders can live their whole lives in one plant.

Possible applications:

materials with embedded nutrients for better health,

plant holders that automatically feed them.

original photograph by Robert Kramer

parasitism

common cuckoo
cuculus canorus

+

dunnock
prunella modularis

Parasites in nature are usually seen as a pest and things to be avoided and expelled. Many animals turn to plants to aid them in avoiding parasites. Starlings use fragrant and antiseptic herbs to line their nests in order to keep parasites away from their young chicks. Chimpanzees have learned to eat certain leaves in order to prevent or expel intestinal parasites. But Cuckoo birds are an organism that use parasitism to ensure their species' survival. They place their eggs in foreign nests; the cuckoo hatchlings hatch first and then push the original eggs out and force the new mothers to raise them instead. Parasites offer interesting lessons in terms of strategies of avoidance but also in adaptability and co-evolution.

Possible applications

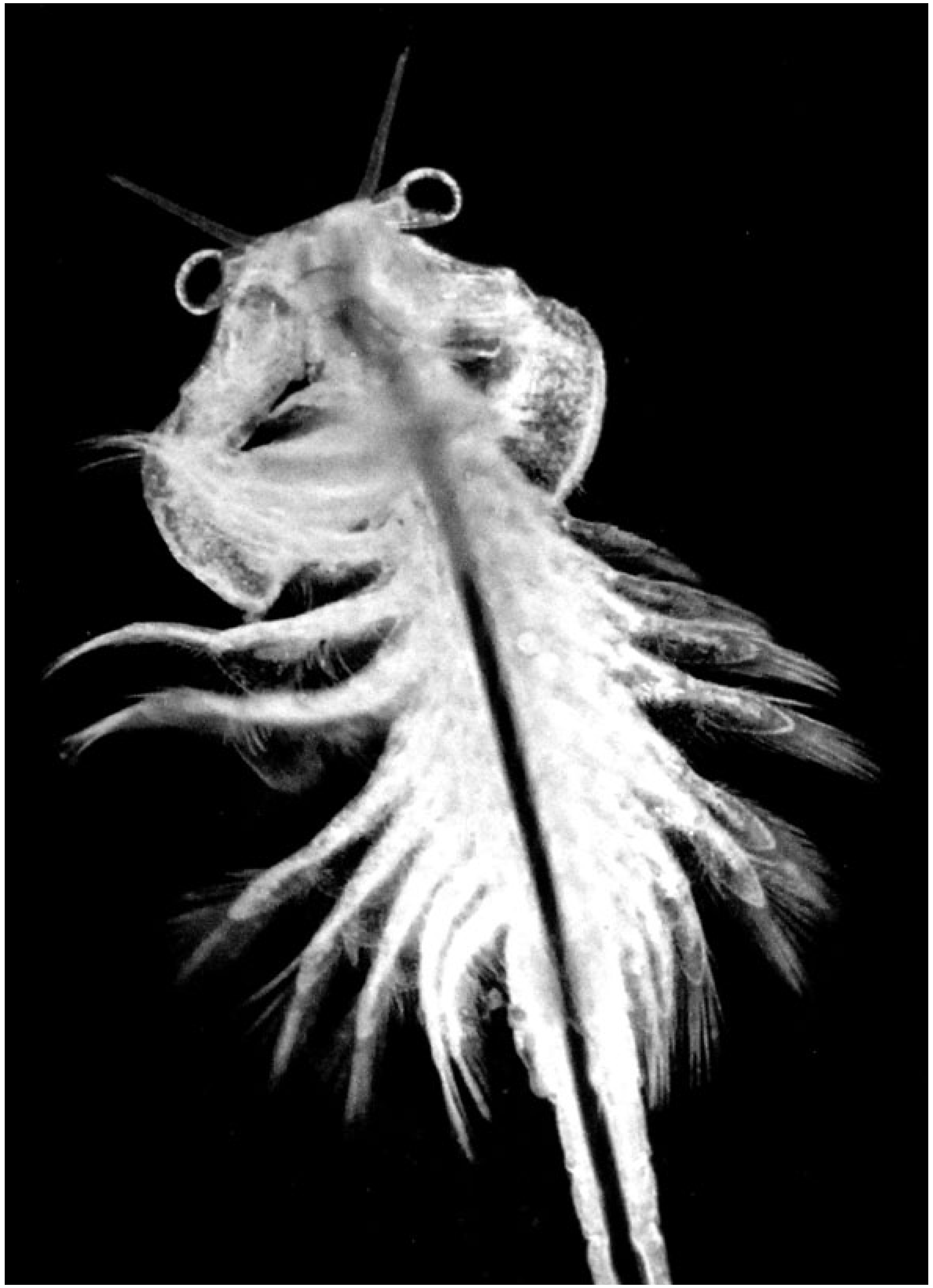
temporary living systems that tap into larger systems,

central utility hubs,

modular living systems,

materials that prevent infestation,

materials that kill bacteria.



original photograph by microimaging.ca

living at the edge

brine shrimp

artemia salina

The brine shrimp is part of a rare group of organisms, along with the tardigrade or water bear, that can be considered cryptobiotic. Cryptobiosis is a reversible, suspended metabolic state which allows an organism to live in extreme conditions without dying. These conditions could be extreme heat, salinity, cold, or dryness. Brine shrimp have adapted to withstand all of these. The shrimp actually prefer a salinity level of 8% (with seawater being 3.5%) but can tolerate up to 25% and their eggs can survive dessication for years at a time. This suspended state of metabolism is called diapause, which only a select group can achieve, usually only in response to cold climates. Among this group are the Siberian salamander, the whiskered bat and the wood frog whose blood can drop below freezing without damage to living cells.

Possible applications

vaccine and medicine storage,

medical supplies or organ storage with refrigeration,

food transportation without refrigeration.

get outside!

inspirational ecosystems

salt marsh

design problems

high salinity
sun exposure
submersion/dessication
anoxic mud (lacking oxygen)
tidal surges
lack of fresh water
chemical build-up
waste removal/decomposition

inspirational organisms

salicornia
cordgrass
white pelican
salt marsh harvest mouse
great blue heron
snowy egret
clapper rail
phalarope
ghost shrimp
brine shrimp
burrowing owl
grey fox
eel grass

redwood forest

design problems

low sun exposure
high humidity
small temperature fluctuations
soil drainage issues
lack of nutrients
low biological diversity
waste removal/decomposition

inspirational organisms

coast redwood
steelhead trout
spotted owl
california bay laurel
tanoak
big brown bat
pileated woodpecker
american shrew mole
white-tailed deer
big leaf maple

coastal mountain

design problems

- drought
- variable seasonal temperatures
- sun exposure
- waste removal/decomposition

inspirational organisms

- red fox
- knobcone pine
- bald eagle
- golden eagle
- coyote
- bobcat
- northern pacific rattlesnake
- mountain lions
- california red-legged frog
- peregrine falcon
- roadrunners
- california tiger salamander
- burrowing owls
- tarantula

rocky coast

design problems

- high salinity
- sun exposure
- submersion/dessication
- erosion
- tidal surges
- lack of fresh water
- wave action
- waste removal/decomposition

inspirational organisms

- bull kelp
- sea palm
- chiton
- sea cucumber
- whelk
- hermit crab
- limpet
- sea lettuce
- turkish towel
- mussel
- brown pelican
- grebe
- bat star
- anemone

sandy coast

design problems

high salinity
submersion/dessication
erosion
tidal surges
lack of fresh water
wave action

inspirational organisms

sand piper
sand dollar
beach verbena
beach pea
ghost crab
grebe
leopard sharks
bat rays
lupine
dune sedge
beach flea

riparian

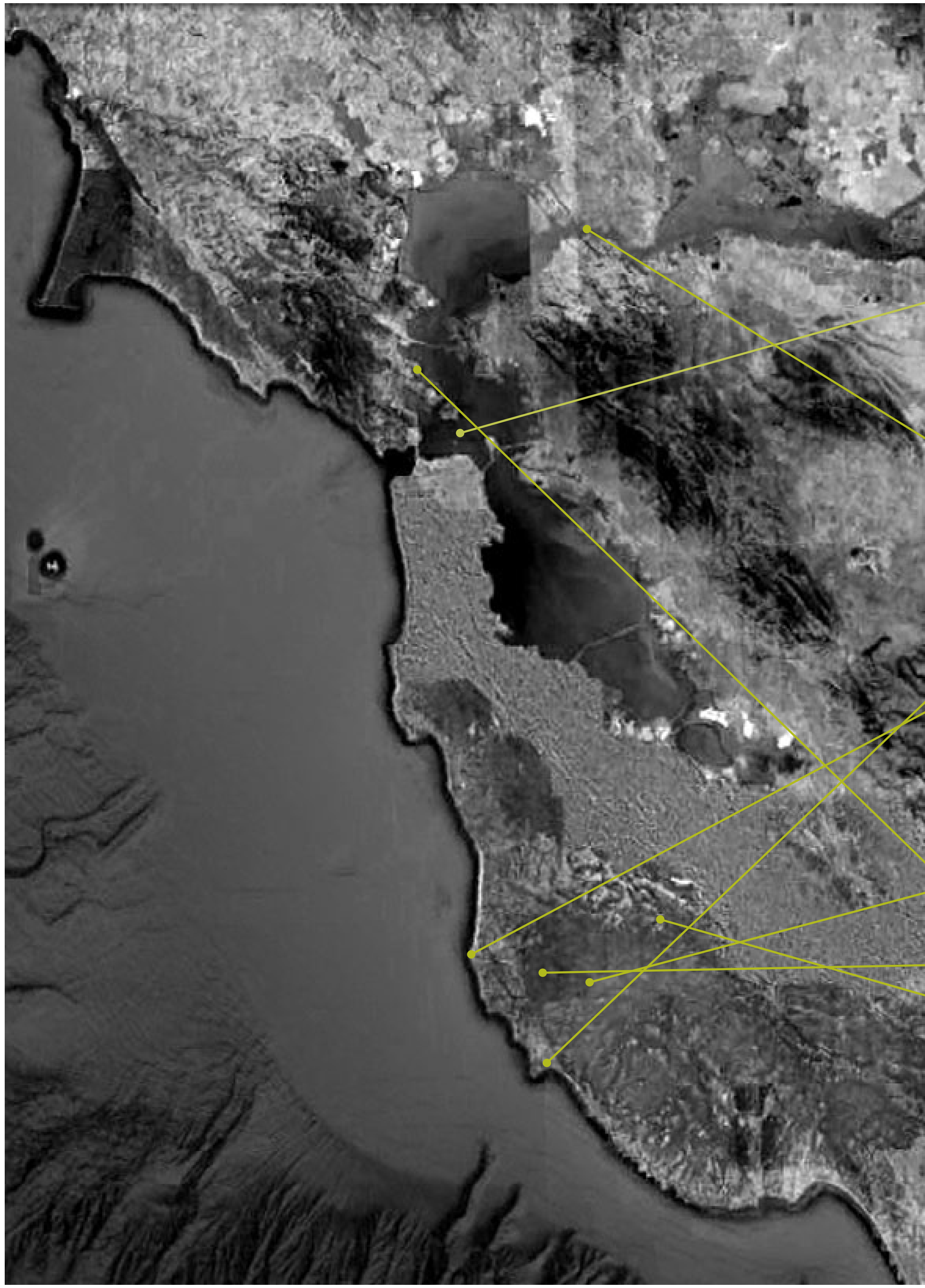
design problems

flooding
variable seasonal temperatures
sun exposure/lack of sun
drought
waste removal/decomposition

inspirational organisms

golden eagle
coyote
tree frog
raven
warblers
california tiger salamander
trout
water strider
giant water beetle
redwing blackbird
alder
heron
nasturtium

places to go


satellite image courtesy of google earth

bay area nature reserves

Angel Island State Park
Island nature reserve in the middle of San Francisco bay. Camping, biking, boating, scenic views of the bay area.
Angel Island Association
P.O. Box 866, Tiburon, CA 94920

Año Nuevo State Park
Breeding grounds for Elephant seals, Stellar sea lions, California sea lions, and Harbor seals, with occasional fur seals and sea otters. Sea bird nesting colonies, hiking.
Pescadero, San Mateo County, CA

Bean Hollow State Beach
Tide pools with anemones, crab, sea urchins and other marine inhabitants. Self-guided nature trail.
San Mateo County, CA

Benicia State Recreation Area
720 acres of marsh, grassy hillsides and rocky beaches along the Carquinez Strait. Hiking, biking and bird watching.
Benicia, CA 94510

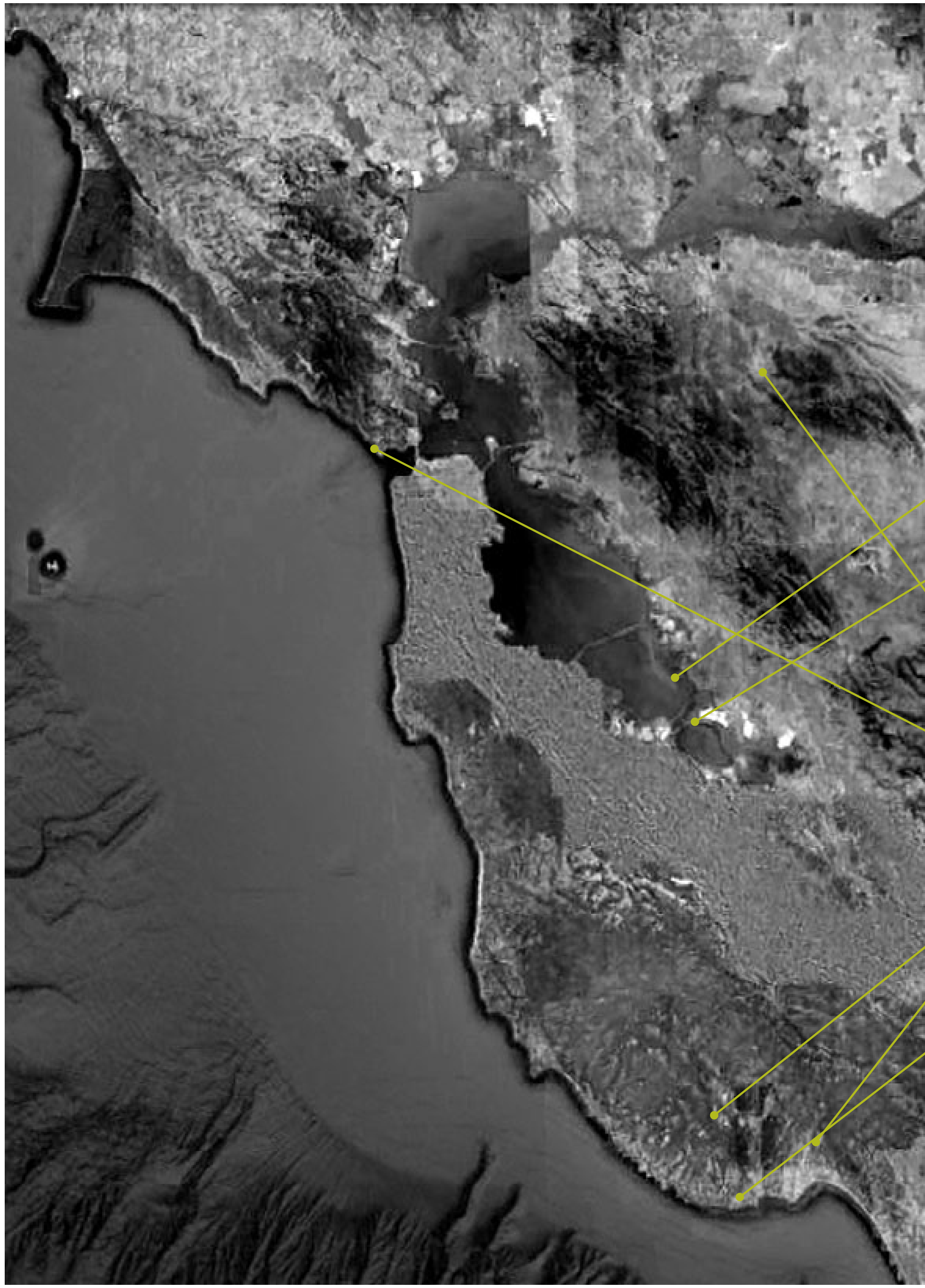
Big Basin Redwoods State Park
18,000 acres and over 80 miles of forested trails. Largest stand of Coast Redwoods south of San Francisco. Waterfalls, wildlife and even mountain lions.
21600 Big Basin Way, Boulder Creek, CA 95006

Butano State Park
2,200 acres of secluded redwood-filled canyon. Hiking, camping, weekend campfire programs during the summer.
Pescadero, CA, 94060

Castle Rock State Park
Rock climbing, horseback riding trails, hiking. camping.
Santa Cruz County/Santa Clara County, CA

China Camp State Park
15 miles of hiking trails, wildlife, swimming, boating.
101 Peacock Gap Trail, San Rafael, CA 94901

places to go



satellite image courtesy of google earth

bay area nature reserves

Coyote Hills Regional Park
Hiking, bicycling, marsh and hillside wildlife.
8000 Patterson Ranch Road, Fremont, CA 94555

Don Edwards San Francisco Bay National Wildlife Refuge
30,000 acres of open bay, salt pond, salt marsh, mud flat, upland and vernal pool habitats. Located along the Pacific Flyway, the Refuge hosts over 280 species of birds.
9500 Thornton Ave, Newark, CA 94560

The Forest of Nisene Marks State Park
30 miles of trails, hiking, and biking, wildlife.
Aptos Creek Road, Aptos, CA, 95001

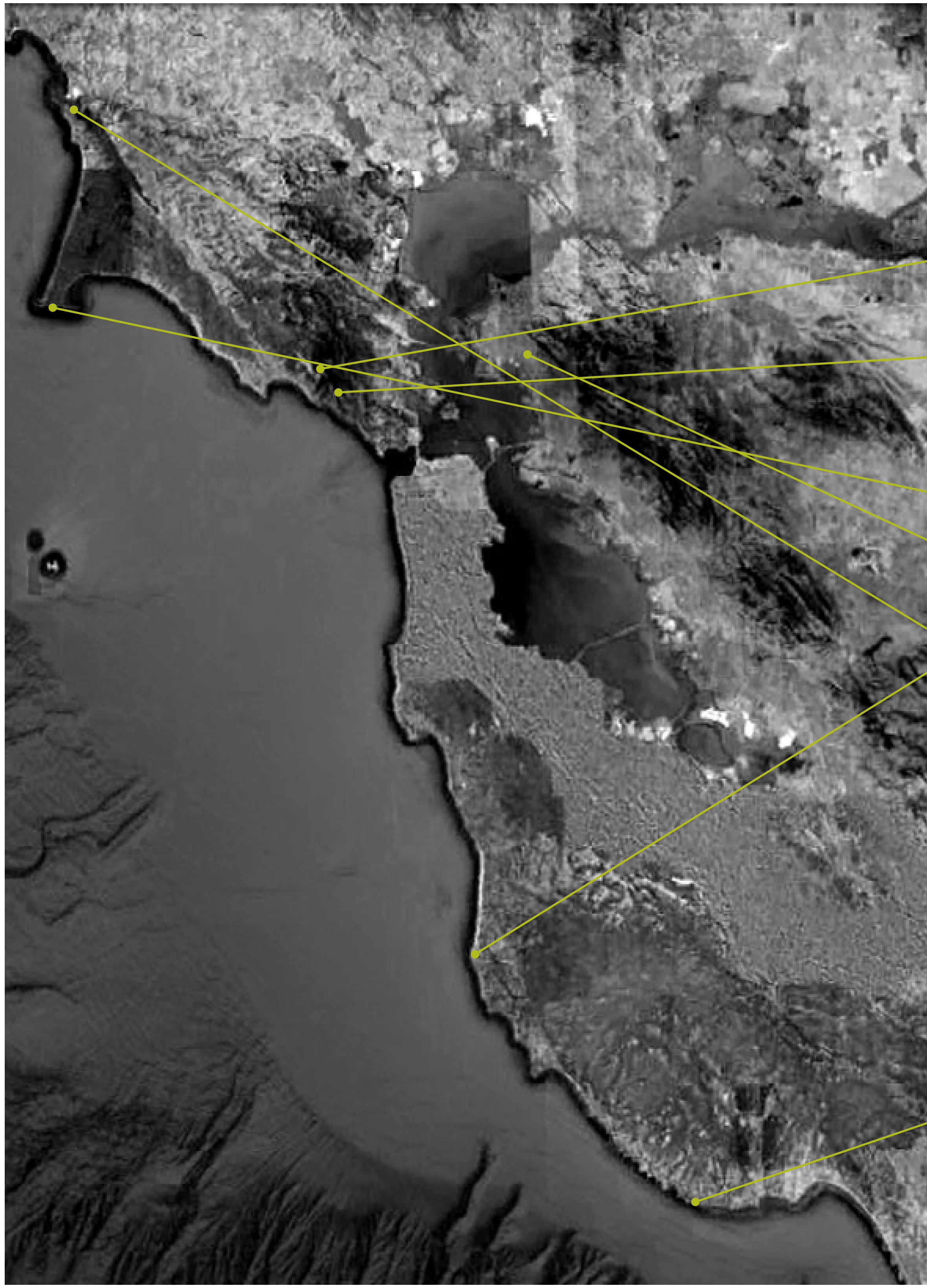
Henry Cowell Redwoods Park
15 miles of hiking and riding trails through a redwood forest.
101 North Big Trees Park Road, Felton, CA 95018

Lighthouse Field
Hiking, surfing, bird-watching. Monarch butterflies stop here on their yearly migration.
701 West Cliff Drive, Santa Cruz, CA 95060

Marin Headlands
Hiking, beaches, tide pools, birding, swimming, wildlife. Marine Mammal Center, Foundation for Deep Ecology, and Headlands Center for the Arts and the Tennessee Valley Native Plant Nurseries.

Mount Diablo State Park
3,849 foot summit, hiking, biking, horseback riding and camping. Wildflowers, wildlife and rock formations.
96 Mitchell Canyon Road, Clayton, CA 94517

places to go



satellite image courtesy of google earth

bay area nature reserves

Mount Tamalpais State Park
2,571-foot peak, 50 miles of trail, hiking, biking, boating. wildlife and forests.
801 Panoramic Highway, Mill Valley, CA 94941

Muir Woods National Monument
559 acres of old growth redwoods, hiking, wildlife.
Muir Woods National Monument, Mill Valley, CA 94941

Pescadero State Park
Sandy coves, rocky cliffs, tide pools, marshland, birding.
Pescadero, CA 94060

Point Reyes National Seashore
Hiking, sea kayaking, bird watching. 70,000 acres of habitat with 490 species of bird.
1 Bear Valley Road, Point Reyes Station, CA 94956

Tilden Park Regional Park
Hiking, horseback riding, bicycling, boating, botanical garden, wildlife.
Grizzly Peak Boulevard, Berkeley, CA

Tomales Bay
15 mile long, 1 mile wide bay, which was formed by the coastal emergence of the San Andreas fault. Kayaking, boating, swimming.
Point Reyes, CA

Wilder Ranch State Park
34 miles of hiking, biking and equestrian trails winding through coastal terraces and valleys.
Santa Cruz, California

resources

6 : resources
where to learn more

websites

Ask Nature Database
www.asknature.org

Autodesk's biomimicry page
http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=12089947

Biomimicry Europa
www.biomimicryeuropa.org

Biomimicry Guild
www.biomimicryguild.com

Biomimicry Institute
www.biomimicryinstitute.org

Biomimicry News
www.biomimicrynews.com

Bioneers
www.bioneers.org

Buckminster Fuller Institute
bfi.org

Clippings, The Biomimicry Institute's Blog
biomimicry.typepad.com

Core77
biomimicry.typepad.com

Design Inspiration
mdecola.blogspot.com

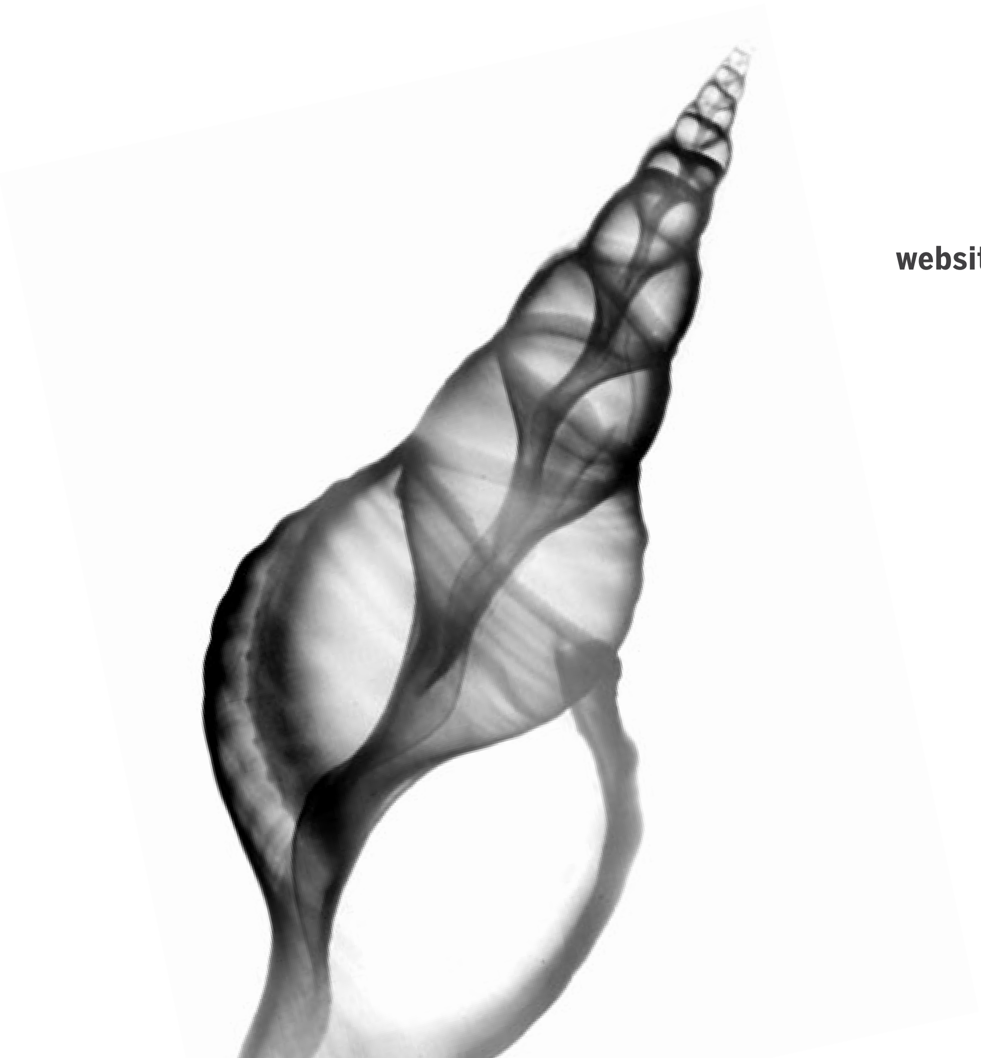
Encyclopedia of Life
www.eol.org

Exploration Architecture
www.exploration-architecture.com

Greenbiz.com
www.greenbiz.com

Hidden Ecologies
www.exploratorium.edu/id/hidden.html

HOK's sustainable design site
www.hok.com/sustainable



Inhabitat
www.inhabitat.com

Janine Benyus' Biomimicry TED Presentation
www.ted.com/talks/janine_benyus_shares_nature_s_designs.html

John Todd Ecological Design
www.toddecological.com

Material Belief's interview with Julian Vincent
www.materialbeliefs.com/collaboration/julian-v.php

Omega Center for Sustainable Living
www.eomega.org/omega/about/ocsl

Pax Scientific
www.paxscientific.com

Robert Full's Animal Movement TED Presentation
www.ted.com/talks/lang/eng/robert_full_on_animal_movement.html

Ross Lovegrove's Organic Design TED Presentation
www.ted.com/talks/lang/eng/ross_lovegrove_shares_organic_designs.html

Sensing Architecture
sensingarchitecture.com

The Journal of Ecological Design
www.ecotecture.com

Treehugger
www.treehugger.com

United States Green Building Council
www.usgbc.org

Wayne Lanier's microbiology website
www.hikingwithafieldmicroscope.com

WikiSpecies
species.wikimedia.org

Worldchanging
www.worldchanging.com

where to learn more

books and publications

Attenborough, David. **The Private Life of Plants : A Natural History of Plant Behavior**, **The Life of Birds** and **The Life of Mammals**. London: BBC Books. 1995.

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schools with biomimicry curricula

Aquinas College, Center for Sustainability
www.centerforsustainability.org

Auburn University, College of Architecture, Design and Construction
www.cadc.auburn.edu

The Biomimetics Network for Industrial Sustainability (BIONIS)
www.extra.rdg.ac.uk/eng/BIONIS

California College of the Arts
www.cca.edu

Curtin University of Technology, Ecomimicry Project
ecomimicry.net

Georgia Institute of Technology, Center for Biologically Inspired Design (CBID)
www.cbid.gatech.edu

Minneapolis College of Arts and Design
www.mcad.edu

Ontario College of Arts & Design
www.ocad.ca

Stanford University, Bio-X
biox.stanford.edu/about/index.html

State University of NY, College of Environmental Science and Forestry
www.esf.edu

Universidad Iberoamericana
www.uia.mx

University of Applied Sciences, Bremen
bionik.fbsm.hs-bremen.de

University of Arizona
http://www.arizona.edu

University of Bath: The Centre for Biomimetic and Natural Technologies
www.bath.ac.uk/mech-eng/biomimetics

University of California at Berkeley, Center for Integrative Biomechanics in Education and Research
ciber.berkeley.edu/twiki/bin/view/CIBER/WebHome

University of Medicine and Pharmaci of Iasi
www.biomateriale.ro/engl.html

University of Montana
www.umt.edu

University of New Mexico, School of Architecture
saap.unm.edu

University of Reading, Centre for Biomimetics
www.reading.ac.uk/biomim

Royal Institute of Technology, Swedish Center of Biomimetic Fiber Engineering (BiomimeT)
www.biomime.org

University of Toronto, Biomimetics for Innovation and Design Laboratory
www.mie.utoronto.ca/labs/bidlab

thank you

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